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(54) Title: APPARATUS FOR TRACKING RESONANT FREQUENCY

(57) Abstract

An apparatus for tracking the varying resonant frequency of an electrically resonant structure, characterised by: a variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency range of said resonant structure, a bidirectional RF transmission line connecting said variable frequency oscillator and said resonant structure, said transmission line incorporating a directional coupler which generates a directional coupler signal proportional to the reflected signal from said resonant structure, said directional coupler signal being conditioned by a processor to provide a feedback signal to the input of the variable frequency oscillator, such that the mean frequency of said excitation signal is caused to continuously track the varying resonant frequency of said resonant structure. Typically the tracking of said varying resonant frequency involves at least two functions, a first search function for initially searching the possible resonant frequency range of said resonant structure and, once resonance of said resonant structure is established, a second following function for following said variable resonant frequency as it varies as a function of time.

APPARATUS FOR TRACKING RESONANT FREQUENCY.

TECHNICAL FIELD

This invention relates to a method and apparatus for tracking the varying resonant frequency of an electrically resonant structure. More particularly the invention is directed towards applications where said structure is mounted remotely from the driving and sensing electronics.

BACKGROUND ART

The prior art most closely related to that of the present invention is the technique for determining the excitation frequency of rubidium electrons in a rubidium gas cell atomic clock (as described in model 304BR Rubidium Frequency Standard, Tracor Inc. 1968). The rubidium atoms in the closed gas cell are excited by an alternating electromagnetic field of very high frequency. If the frequency exactly matches the spin frequency of the electrons in the outer shell of the rubidium atoms, the electrons will change energy state. To measure this change, optical radiation is shone through the cell and detected by a photo diode. The light intensity is at a minimum when the atoms are excited at the correct frequency. To detect this minimum, the excitation frequency is swept a small amount either side of resonance and the output of the photo detector is applied as feedback to the exciting frequency to allow the minimum light intensity to be maintained.

Although the basic philosophy of this prior art is similar to the present invention, the technical field of the invention is completely divorced and the method of implementation is completely different. The object of this invention is to track the resonant frequency of an electrically resonant structure whose resonant frequency varies continuously with time. An example of such a structure is a surface acoustic wave (SAW) resonator used as a strain or temperature sensor as described in our European Patent 0518900.

SUMMARY OF INVENTION

The first aspect of the present invention is an apparatus for tracking the varying resonant frequency of an electrically resonant structure, characterised in that it comprises a

variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency range of said resonant structure, a bidirectional RF transmission line connecting said variable frequency oscillator and said resonant structure, a directional coupler incorporated in the transmission line which generates a directional coupler signal proportional to the reflected signal from said resonant structure, said directional coupler signal being conditioned by a processor to provide a feedback signal to the input of the variable frequency oscillator, such that the mean frequency of said excitation signal is caused to continuously track the varying resonant frequency of said resonant structure.

Preferably the tracking of said varying resonant frequency involves at least two functions, a first search function for initially searching the possible resonant frequency range of said resonant structure and, once resonance of said resonant structure is established, a second following function for following said variable resonant frequency as it varies as a function of time.

Preferably, in a first embodiment, said processor comprises a detector which detects said directional coupler signal, a synchronous rectifier for selectively rectifying the output of the detector relative to phase a frequency source having at least one master frequency output driving said synchronous rectifier, an integrator for conditioning the output from said synchronous rectifier, said integrator being input into a summer which also receives a second input from said frequency source for modulating the feedback signal to said variable frequency oscillator, thereby providing said following function It is preferred that said second input from said frequency source is synchronised with said master frequency output of said frequency source.

Preferably said frequency source also provides a search frequency output which is substantially lower than said master frequency output. The search frequency output being input into said integrator and therefore causing said variable frequency oscillator to sweep through said possible resonant frequency range of said resonant structure in the absence of any feedback signal.

Preferably the output of said variable frequency oscillator is monitored to indicate the resonant frequency of said electrically resonant structure. Alternatively or additionally, an analogue signal from the output of said integrator or summer may be used indicate

the resonant frequency of said resonant structure.

Preferably, in a second embodiment, said processor comprises a double balance mixer which receives said directional coupler signal from said directional coupler and said excitation signal from said variable frequency oscillator and provides a phase proportional DC output to an integrator for conditioning the output of said integrator providing said feedback signal to the variable frequency oscillator, thereby providing said following function.

Preferably the electrically resonant structure is at least partially composed of piezoelectric material. Suitable piezoelectric materials include quartz and directionally orientated zinc oxide.

Preferably the electrically resonant structure is electrically excited by means of at least one interdigital array (IDA). Suitable resonant structures which incorporate IDAs are surface acoustic wave (SAW) resonators, shallow bulk acoustic wave (SBAW) resonators or the like. Preferably the variable impedance of the resonant structure results from the variation in the pitch of the IDA or mass loading of the resonant structure.

Preferably the variation in the pitch of the IDA results from strain of the resonant structure.

Preferably the resonant structure is substantially rigidly mounted to a surface subject to strain, and this strain is therefore imparted to said resonant structure.

Strain of said surface may be caused by physical quantities such as applied load, applied bending moment, applied pressure, or thermal expansion caused by temperature

Mass loading of the resonant structure may be caused by absorption of fluids into the surface of the resonant structure in the presence of specific fluids or by physical quantities such as humidity.

Preferably the directional coupler may be a transformer, Maxwell Bridge (wire line) or Lange coupler.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will now be described by way of example with reference to the
accompanying drawings of which:
Figure 1 is a schematic layout depicting a first embodiment of the present invention;
Figure 2 is a schematic layout of the internal components of the processor of the first
embodiment of the present invention shown in Figure 1, to enable the following
function;
Figure 3 is a schematic layout of the internal components of the processor of the first
embodiment of the present invention shown in Figure 1, to enable the searching
function; and
Figure 4 is a schematic layout depicting a second embodiment of the present invention.

Mode of Carrying Out Invention

Figure 1 shows a basic circuit diagram of the first aspect of the invention. Variable
frequency oscillator (VFO) 1 is electrically connected to electrically resonant structure 2
of varying resonant frequency via bidirectional RF transmission line 3 incorporating
directional coupler 4. The output of directional coupler 4 is connected to the input of
processor 5 If the resonant frequency of structure 2 is such that it exactly matches the
frequency supplied by VFO 1, all the energy supplied to structure 2 will be dissipated by
structure 2, and none will be reflected back to VFO 1. As the resonant frequency of
structure 2 varies during its operation, the frequency supplied by VFO 1 will no longer
match the resonant frequency of the circuit, and energy will be reflected back to VFO 1
from structure 2. Directional coupler 4 serves to measure this reflected energy return.
Directional coupler 4 may preferably be one of many known types, including a
transformer, a Maxwell Bridge (sometimes known as a wire line) or a Lange coupler. The
output of directional coupler 4, henceforth termed the directional coupler signal 11, is
frequency synchronised with the excitation frequency, but with amplitude and phase
modulated as a function of the difference between the excitation frequency supplied by
VFO 1 and the resonant frequency of structure 2. The amplitude of directional coupler
signal 11 is at a minimum when the frequency of the excitation signal supplied by source
1 matches the resonant frequency of structure 2, and increases as the resonant frequency
of the structure moves away from the matched condition. The coupler signal 11 does not

serve to indicate whether the resonant frequency of structure 2 is higher or lower than
that of VFO 1, only the absolute amount of mismatch. The phase of directional coupler
signal 11 relative to the excitation signal supplied by VFO 1 yields the direction of
mismatch. By utilising the output received from directional coupler 4, processor 5 is able
to control the output of VFO 1 so as the mean output frequency is equal to the resonant
frequency of structure 2 at any point in time, henceforth termed a following function. A
more detailed description can be found in our co-pending PCT Patent Application
entitled 'Apparatus for Measuring Impedance of a Resonant Structure' filed on the same
date as the present application.

An alternative embodiment of the system could include an in-line coupler (not shown)
between VFO 1 and structure 2 as also described in the above referenced co-pending
PCT Application. This would allow non contact measurement of the resonant frequency
of structure 2 if it were mounted, for example, on a rotating shaft.

Figure 2 in conjunction with Figure 1 serve to show one embodiment of processor 5
which will enable the following function to be carried out. Directional coupler signal 11
is rectified by detector 12 to yield a waveform at substantially the same frequency as the
excitation signal supplied by VFO 1 to resonant structure 2 with an amplitude varying
from zero volts to a maximum. Decoupler 13 AC couples directional coupler signal 11
resulting in a waveform symmetrical about zero volts. Synchronous rectifier 14 then
rectifies the signal relative to a synchronising input frequency (f_1) supplied by master
frequency source 15. The resulting output of synchronous rectifier 14 is thus a signal
whose RMS DC level is a function of (a) the phase difference between the input to
synchronous rectifier 14 and master frequency source 15 and (b) the amplitude of the
input to the synchronous rectifier 14. The output of synchronous rectifier 14 is fed to
integrator 16 whose output is proportional to the product of the RMS value of the input
and time. The output of integrator 16 is then supplied to summer 17 which has a second
input supplied by master frequency sourceE15. The output of summer 7 is therefore a
DC value supplied by integrator 16 with a superimposed AC component supplied by
master frequency source 15. This output is the control signal supplied to VFO 1 in
Figure 1, henceforth termed feedback signal 18. The excitation signal supplied by VFO 1,
is a frequency whose mean value is a function of the DC level supplied by integrator 16,
which has a frequency modulation of amplitude and frequency being a function of the
master frequency from master frequency source 15. In this way the mean frequency of

the excitation signal supplied by VFO 1, at any point in time, is the instantaneous resonant frequency of structure 1 and can be measured and displayed as such. Alternately, the output of integrator 16 will provide an analogue signal proportional to the resonant frequency, and this signal can be measured and calibrated to give a direct reading of the resonant frequency.

Figure 3 shows an embodiment with additions to processor 5 shown in Figure 2 which will enable a search function to be carried out. The components which make up processor 5 remain the same as that shown in Figure 2. Additions to the circuit comprise frequency source 19 to provide a search frequency (f_2) of a value substantially lower than the master frequency, a voltage reference source 22, a comparator 21 and a change over switch 20 operated by the output of comparator 21. When the frequency of the excitation signal supplied by VFO 1 is substantially different from the resonant frequency of structure 2, the output of synchronous rectifier 14 will be a comparatively large DC voltage. This output is supplied to one input of comparator 21, the other input being supplied by reference voltage (V_{ref}) from source 22. If the output voltage of synchronous rectifier 14 is larger than this reference voltage, comparator 21 activates changeover switch 20 which disconnects the input of integrator 16 from synchronous rectifier 14 and connects it to frequency source 19. In this mode, the output of integrator 16 sweeps from a minimum value to a maximum value and back continuously. This causes VFO 1 to sweep the excitation signal over a frequency range which will encompass all possible resonant frequencies of structure 2. As the excitation signal frequency approaches the resonant frequency of structure 2, the output voltage from synchronous rectifier 14 will begin to fall. When the voltage becomes less than the reference voltage, comparator 21 will deactivate changeover switch 20 and the circuit will enter the previously described following function mode. The changeover from search function to following function must occur when the excitation frequency is sufficiently close to the resonant frequency, so as to allow the following function to track the resonant frequency. The reference voltage supplied to comparator 21 must therefore be of a sufficiently low value as to allow the transition from the search function to the following function to occur successfully. The reference voltage must also be of a sufficiently high value to allow the approach of resonance to be detected and the changeover to occur. The output from comparator 21 may be used to supply an indication that, while the search function is enabled, the frequency of the excitation signal supplied by VFO 1 is not the resonant frequency of structure 2.

An embodiment of the second aspect of the invention is shown in Figure 4. Two electrically resonant structures 24 and 29 are mounted on a surface such that when the surface is strained in a given direction, a differential strain is applied to each of structures 24 and 29. Each structure 24, 29 is electrically connected to tracking apparatuses via bidirectional RF transmission lines 23, 28 respectively, which incorporate directional couplers 25, 30 respectively. The tracking apparatuses consist of VFOs 22, 27 respectively and processors 31, 26 respectively. The output of directional couplers 25, 30 are connected to the input of processors 31, 26 respectively. The operation of processors 31, 26 is as discussed earlier for processor 5, with the addition of synchronising signal 41 linking processors 31 and 26. The purpose of synchronising signal 41 is to link the master frequency sources of both processors 31 and 26. Alternatively, in a not shown embodiment one master frequency source could supply both processors.

In an alternative embodiment (not shown) the system can include in-line couplers between VFOs 22 and 27 and, respectively, structures 24 and 29 as described in our earlier mentioned co-ending PCT Application. This provides for non contact measurement of the resonant frequencies of structures 24 and 29 if they were mounted, for example, on a rotating shaft.

The outputs of VFOs 22 and 27 are input to mixer 32 with two outputs. The first output is the difference in frequency between the excitation signals of the two VFOs 22 and 27, and the second output is the sum of the frequencies of the excitation signals of the two VFOs 22 and 27. By synchronising the master frequency sources for all processors as described above, the frequency modulation of all VFOs will be synchronised, and therefore the frequency difference between any pair of VFOs will not include this modulation. By arranging structures 24 and 29 to have resonant frequencies which differ in the unstrained condition, the first output from mixer 32 will be a frequency representing the difference in resonant frequency between the two unstrained structures 24 and 29. As the surface upon which structures 24 and 29 are attached is strained, the frequency measured at the first output of the mixer would rise or fall giving information containing both the magnitude and direction of the strain. Alternatively, structures 24 and 29 may have substantially the same resonant frequency, in which case only information containing the magnitude of the strain would be obtained.

In the above mentioned embodiments the electrically resonant structures 2, 24 and 29 are preferably surface acoustic wave ('SAW') resonators, shallow bulk acoustic wave ('SBAW') resonators or similar, which are partially composed of a piezoelectric material, such as quartz or directionally orientated zinc oxide. Such resonators comprise an interdigital array ('IDA') which is able to electrically excite the resonator. As discussed in the above mentioned co-pending PCT Application, the change in impedance of structure 2 can be utilised to measure various physical quantities of interest. The physical quantity being measured may for example be strain imparted to structure 2 due to the straining of a surface to which structure 2 is substantially rigidly mounted. Strain of this surface may, for example, be caused by physical quantities such as an applied load, applied bending moment, pressure or temperature causing thermal expansion of the surface. Alternatively change in impedance of structure 2 may be caused directly by mass loading of structure 2 due to absorption of fluids resulting from changes in humidity or presence of specific fluids.

The apparatus and method of the present invention requires very low signal excitation power to be provided by the respective one or more VFOs and can utilise a resonant structure mounted remotely from the driving and sensing electronics. It is therefore also suited to other applications and environments where very low excitation signal power is desirable such as in high temperature and/or explosive environments where physical quantities such as strain, load, pressure, temperature, humidity, fluid presence, etc. are measured.

It will be recognised by persons skilled in the art that numerous variations and modifications may be made to the invention without departing from the spirit and scope of the invention.

CLAIMS

1   An apparatus for tracking the varying resonant frequency of an electrically
        resonant structure, characterised by: a variable frequency oscillator providing an
        excitation signal of a variable frequency encompassing the possible resonant
        frequency range of said resonant structure, a bidirectional RF transmission line
        connecting said variable frequency oscillator and said resonant structure, said
        transmission line incorporating a directional coupler which generates a directional
        coupler signal proportional to the reflected signal from said resonant structure,
        said directional coupler signal being conditioned by a processor to provide a
        feedback signal to the input of the variable frequency oscillator, such that the
        mean frequency of said excitation signal is caused to continuously track the
        varying resonant frequency of said resonant structure.

2   An apparatus as claimed in Claim 1 wherein the tracking of said varying resonant
        frequency involves at least two functions, a first search function for initially
        searching the possible resonant frequency range of said resonant structure and,
        once resonance of said resonant structure is established, a second following
        function for following said variable resonant frequency as it varies as a function of
        time.

3   An apparatus as claimed in any preceding claim wherein said processor comprises
        a detector which detects said directional coupler signal, a synchronous rectifier for
        selectively rectifying the output of the detector relative to phase a frequency
        source having at least one master frequency output driving said synchronous
        rectifier, an integrator for conditioning the output from said synchronous
        rectifier, said integrator being input into a summer which also receives a second
        input from said frequency source for modulating the feedback signal to said
        variable frequency oscillator, thereby providing said following function

4   An apparatus as claimed in Claim 3 wherein said second input from said
        frequency source is synchronised with said master frequency output of said
        frequency source.

5   An apparatus as claimed in Claim 3 or Claim 4 wherein said frequency source also
         provides a search frequency output which is substantially lower than said master
         frequency output and the search frequency output being input into said integrator
         and therefore causing said variable frequency oscillator to sweep through said
         possible resonant frequency range of said resonant structure in the absence of any
         feedback signal.

6   An apparatus as claimed as claimed in any preceding claim wherein the output of
         said variable frequency oscillator is monitored to indicate the resonant frequency
         of said electrically resonant structure.

7   An apparatus as claimed in Claim 3 wherein alternatively or additionally, an
         analogue signal from the output of said integrator or summer may be used
         indicate the resonant frequency of said resonant structure.

8   An apparatus as claimed in any preceding claim wherein said processor comprises
         a double balance mixer which receives said directional coupler signal from said
         directional coupler and said excitation signal from said variable frequency
         oscillator and provides a phase proportional DC output to an integrator for
         conditioning, the output of said integrator providing said feedback signal to the
         variable frequency oscillator, thereby providing said following function.

9   An apparatus as claimed in any preceding claim wherein the electrically resonant
         structure is at least partially composed of piezoelectric material.

10   An apparatus as claimed in Claim 9 wherein the piezoelectric material is selected
         from quartz or directionally orientated zinc oxide.

11   An apparatus as claimed in any preceding wherein the electrically resonant
         structure is electrically excited by means of at least one interdigital array.

12   An apparatus as claimed in claim 11 wherein the resonant structure which
         incorporate at least one interdigital array incorporates surface acoustic wave
         ('SAW') resonators, shallow bulk acoustic wave ('SBAW') resonators or the like.

13   An apparatus as claimed in any preceding claim wherein variable impedance of the
        resonant structure results from the variation in the pitch of the interdigital array
        or mass loading of the resonant structure.

14   An apparatus as claimed in Claim 13 wherein variation in the pitch of the inter
        digital array results from strain of the resonant structure.

15   An apparatus as claimed in any preceding claim wherein the resonant structure is
        substantially rigidly mounted on a surface subject to strain such that the strain is
        therefore imparted to said resonant structure.

16   An apparatus as claimed in Claim 15 wherein the strain is caused by displacement
        such as applied load, applied bending moment, applied pressure, or thermal
        expansion caused by temperature

17.   An apparatus as claimed in Claim 15 wherein the strain is caused by absorption of
        fluids into the surface of the resonant structure in the presence of specific fluids or
        by physical quantities such as humidity.

18   An apparatus as claimed in any preceding claim wherein the directional coupler is
        a transformer, Maxwell Bridge (wire line) or Lange coupler.

19   An apparatus as claimed in any preceding claim wherein the RF transmission line
        incorporates a non-contacting in-line coupler, which may be an untuned or tuned
        transformer, laser, optical, capacitive or RF coupler.

20   An apparatus as claimed in any of preceding claims 1 to 18 wherein the RF
        transmission line is a continuous electrical conductor between the frequency
        source and the resonant structure.

21   An apparatus as claimed in any preceding claim wherein the electrically resonant
        structure is mounted on the surface of a rotating member subject to strain, with
        the in-line coupler allowing the transmission of said excitation signal and said
        reflected signal to and from said rotating member respectively, in a non-contacting
        manner.

22   An apparatus as claimed in any preceding claim wherein output impedance of the
        variable frequency oscillator is substantially conjugately matched to any one of
        said bidirectional RF transmission line, resonant structure, directional coupler, and
        in-line coupler.

23   A device for measuring differential strain incorporating two or more apparatuses
        for tracking the varying resonant frequencies of respective two or more
        electrically resonant structures, characterised in that each tracking apparatus
        comprises a variable frequency oscillator providing an excitation signal of a
        variable frequency encompassing the possible resonant frequency range of its
        respective resonant structure, a bidirectional RF transmission line connecting said
        variable frequency oscillator and said respective resonant structure, said
        transmission line incorporating a directional coupler which generates a directional
        coupler signal proportional to the reflected signal from said respective resonant
        structure, said directional coupler signal conditioned by a processor to provide a
        feedback signal to the input of the variable frequency oscillator, such that the
        mean frequency of said excitation signal is caused to continuously track the
        varying resonant frequency of said respective resonant structure.

24   A device as claimed in Claim 23 wherein the outputs of at least two variable
        frequency oscillators of said two or more apparatuses provide inputs to a mixer,
        the output of which is used to indicate a differential frequency which relates of
        said differential strain.

25   A device as claimed in Claim 23 or Claim 24 wherein the resonant frequencies of
        said two or more resonant structures of respective said apparatuses differ from one
        another.

26   A device as claimed in Claim 23 or Claim 24 wherein said two or more resonant
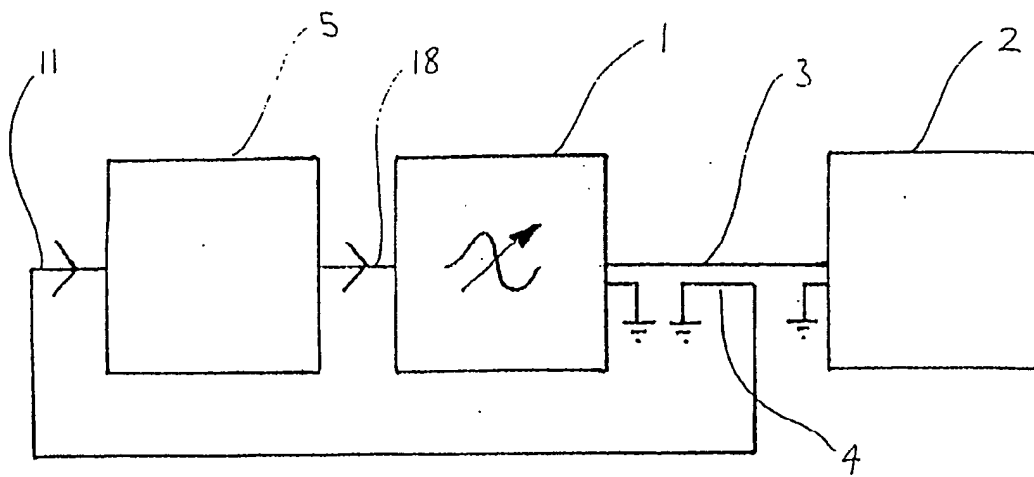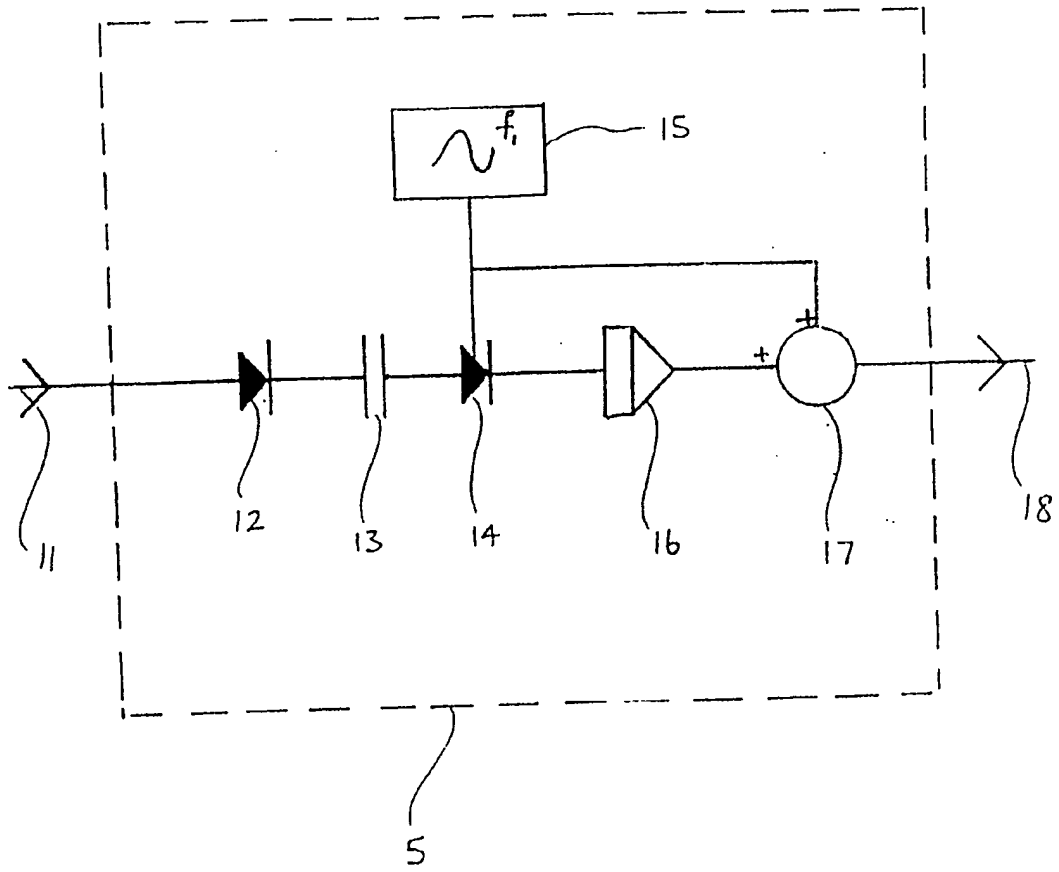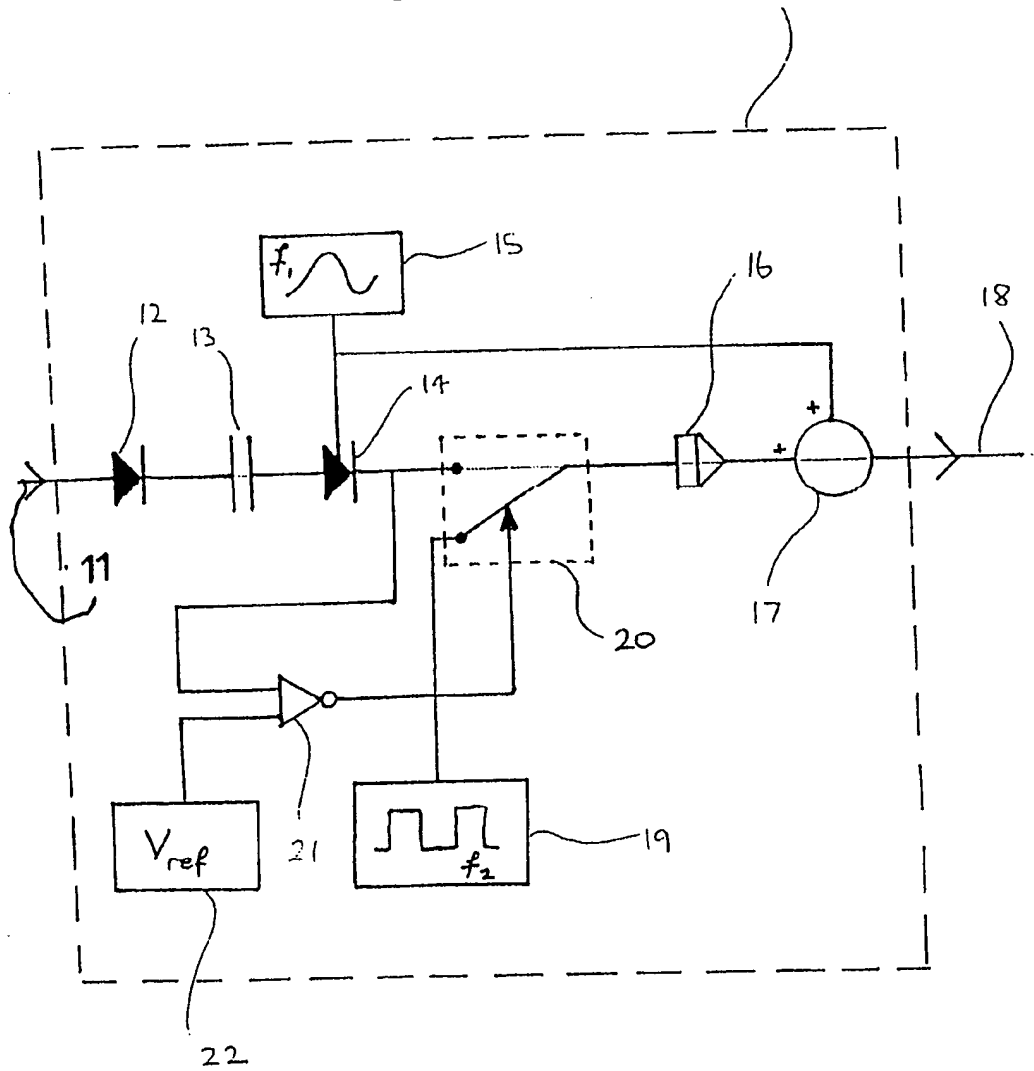   structures may have substantially the same resonant frequency.
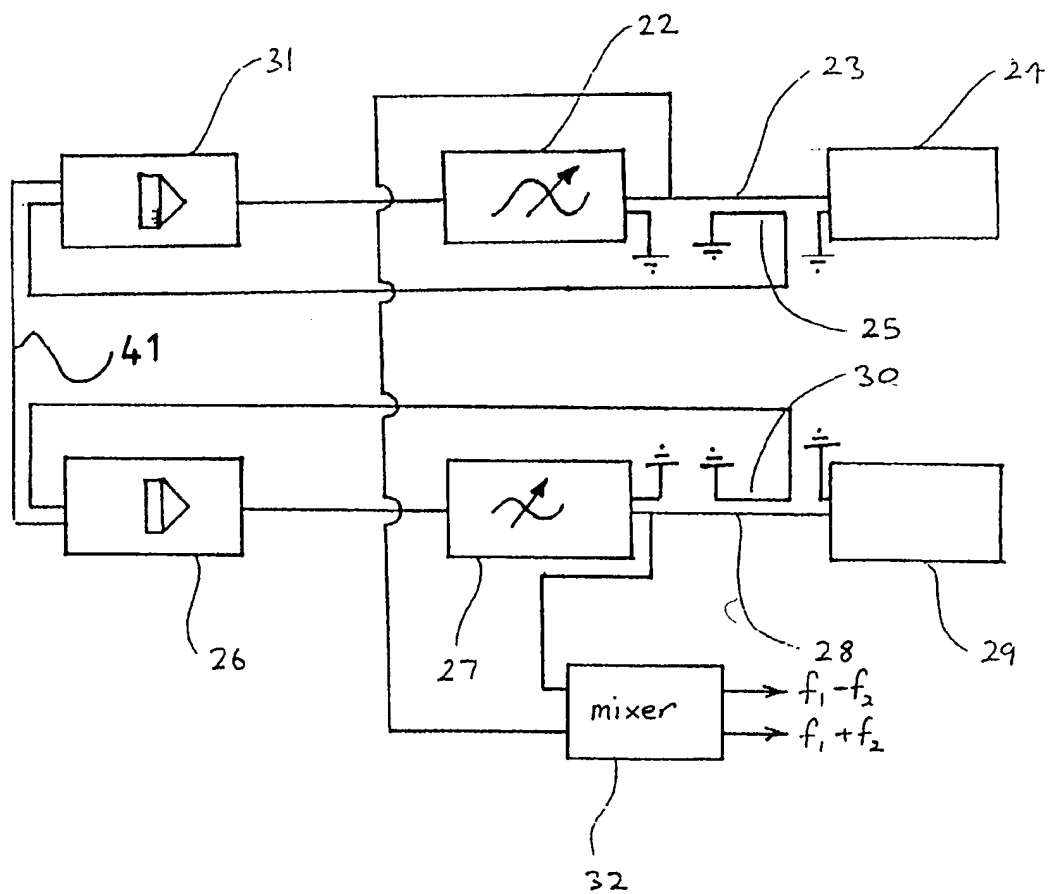
Fig 1

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Fig2

Fig 3

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Fig 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H03B5/32

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H03B   H03L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 019 147 A (THOMSON CSF) 24 October 1979 see page 2, column 1, line 14 - page 3, column 2, line 3; figures 1,3	1
Y	---	23
Y	US 4 100 811 A (D. CULLEN ET. AL.) 18 July 1978 see column 1, line 16 - line 35 see column 2, line 46 - line 58 see column 3, line 9 - line 62; claims 1,2; figure 1 see column 6, line 35 - line 45	23
A	US 3 936 765 A (J. LEWIS) 3 February 1976 see column 2, line 21 - line 66; figures 1,5	1,23
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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 February 1998	02/03/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Butler, N

Form PCT/ISA/210 (second sheet) (July 1992)

Int: .onal Application No
PCT/GB 97/03028

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 760 352 A (D. ASH) 26 July 1988 see column 3, line 34 - line 55; figure 1 ———	1,23
A	WO 91 13832 A (LONSDALE) 19 September 1991 see page 1, line 4 - line 8 see page 4, line 28 - page 5, line 18 see page 9, line 18 - line 25; figures 4,5 —————	1,23

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Information on patent family members

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APPARATUS FOR TRACKING RESONANT FREQUENCY

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Publication date:	2002-08-01
Inventor(s):	LONSDALE BRYAN (GB); LONSDALE ANTHONY (GB)
Applicant(s):	
Requested Patent:	WO9821818
Application Number:	US19990297984 19990728
Priority Number (s):	AU1996PO03590 19961113; WO1997GB03028 19971113
IPC Classification:	G01N29/04
EC Classification:	H03B5/00
Equivalents:	AU5126098, BR9714969, CN1244968, DE69715651D, EP0940004 (WO9821818), B1, JP2001505305T

Abstract

An apparatus for tracking the varying resonant frequency of an electrically resonant structure, characterized by: a variable frequency oscillator providing an excitation signal of a variable frequency encompassing the possible resonant frequency range of the resonant structure, a bidirectional RF transmission line connecting the variable frequency oscillator and the resonant structure, the transmission line incorporating a directional coupler which generates a directional coupler signal proportional to the reflected signal from the resonant structure, the directional coupler signal being conditioned by a processor to provide a feedback signal to the input of the variable frequency oscillator, such that the mean frequency of the excitation signal is caused to continuously track the varying resonant frequency resonant structure. Typically the tracking of the varying resonant frequency involves at least two functions, a first search function for initially searching the possible resonant frequency range of the resonant structure and, once resonance of the resonant structure is established, a second following function for following the variable resonant frequency as it varies as a function of time